AIR FORCE
QUALIFICATION TRAINING PACKAGE (AFQTP)

for

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 22

ELECTRICAL GROUND SYSTEMS

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MODULE 22
ELECTRICAL GROUND SYSTEMS

Career Field Education and Training Plan (CFETP) references from 1 Apr 97 version.

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AIR FORCE QUALIFICATION TRAINING PACKAGES
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ELECTRICAL SYSTEMS
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INTRODUCTION

Before starting this AFQTP, refer to and read the "Trainee/Trainer Guide" located on the AFCESA Web site **http://www.afcesa.af.mil/.** This guide will be found at each AFS's AFQTP download page.

AFQTPs are mandatory and must be completed to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***does not*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks.

MANDATORY minimum upgrade requirements:

Core task:
AFQTP completion
Hands-on certification

Diamond task:
AFQTP completion
CerTest completion (80% minimum to pass)

Note: *Trainees will receive hands-on certification training when equipment becomes available either at home station or at a TDY location.*

Put this package to use. Subject matter experts under the direction and guidance of HQ AFCESA/CEOF revised this AFQTP. If you have any recommendations for improving this document, please contact the Electrical Career Field Manager at the address below.

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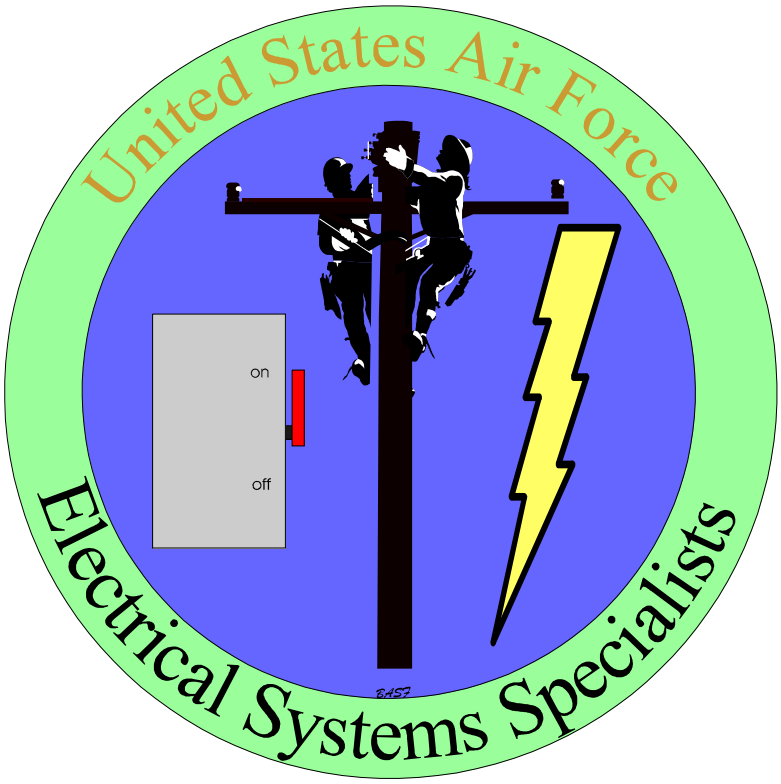
Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.



MAINTAIN

MODULE 22 AFQTP UNIT 3

LIGHTNING PROTECTION SYSTEMS (22.3.1.)

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LIGHTNING PROTECTION SYSTEMS

Task Training Guide

STS Reference Number/Title:	22.3.1. – Electrical ground systems, maintain lightning protection systems
Training References:	• AFI 32 – 1065 • AFP 91–38 • CDC 3E0X1 Set A Vol. 1
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool kit • Multimeter
Learning Objective:	• Given equipment, maintain lightning protection system
Samples of Behavior:	• Follow approved methods to maintain lightning protection systems • Know safety requirements to maintain lightning protection systems
Notes:	
• Any safety violation is an automatic failure.	

LIGHTNING PROTECTION SYSTEMS

Background: The purpose of lightning protection grounds is to safely dissipate lightning strikes into the earth. They are part of a lightning protection system, which usually includes air terminals (lightning rods), down conductors, arresters, and other connectors or fittings required for a complete system. The sole purpose of a lightning protection system is to protect a building, its occupants, and contents from the thermal, mechanical and electrical effects of lightning.

The maintenance of lightning protection systems is closely related to the inspecting and testing of the system. Whenever you think of maintenance of these facilities, your next thought should be inspection. Inspect the lightning protection and grounding systems for buildings and facilities visually and electrically according to Table 1 in AFI 32–1065, *Grounding Systems*.

If you have technical problems or questions, get help from your electrical engineer. Ensure that visual inspections cover all visible parts of the system. Examine connections for tightness and braided wire for damage by lawn mowers or other equipment.

The following is a list of typical areas to look at during self-inspections. The list is only a guide and does not completely cover all areas.

- Has each facility been inspected to determine the type of protection system installed? Is the system integrally mounted, separately mounted mast, or overhead wire?
- Is the lightning protection system connected to a ground loop conductor? (A ground loop conductor is a buried cable surrounding the facility to which the down conductors and grounding rods are connected.)
- Are personnel from the testing agency Base Civil Engineering (BCE) familiar with lightning protection systems? Do they know where the test locations are?
- Do personnel conducting the testing and inspections know where the points for connecting test leads are?
- Are all test agency personnel who could or do perform the tests or inspections familiar with AFI 32–1065 (FORMERLY AFR 91–43) and AFP 91–38, *Maintenance of Electrical Grounding Systems*?
- Are both the user and testing agencies aware of all facilities that have been identified as housing or being used to conduct hazardous operations? Are they familiar with any special test/inspection requirements?
- Are tests being inspected at the required frequency?
- Are large metal masts being checked for continuity to ground?
- Are tests conducted with the proper test instruments?
- Are personnel conducting tests familiar with the location of test points and the relationship between various components of the system being tested?

To perform the task, follow these steps:

Step 1: Perform visual inspection. From a visual inspection, you must be able to determine:

- Is the system in good repair.
- Are there loose connections that might cause high-resistance joints.
- Has corrosion or vibration weakened any part of the system.
- Are all down conductors and ground terminals intact.
- Are all conductors and system components securely fastened to the mounting surfaces. You may need to relocate some connections to better protect them against accidental displacement.
- Have there been additions or alterations to the protected structure, which require additional protection.
- Is there any visual indication of damage to surge suppression (over voltage) devices.
- Does the system follow the Lightning Protection Code in all areas.

Step 2: Correct discrepancies.

- All discrepancies noticed during maintenance must be annotated and repaired.
- After the repair has been made, test the ground to ensure that it complies with standards.

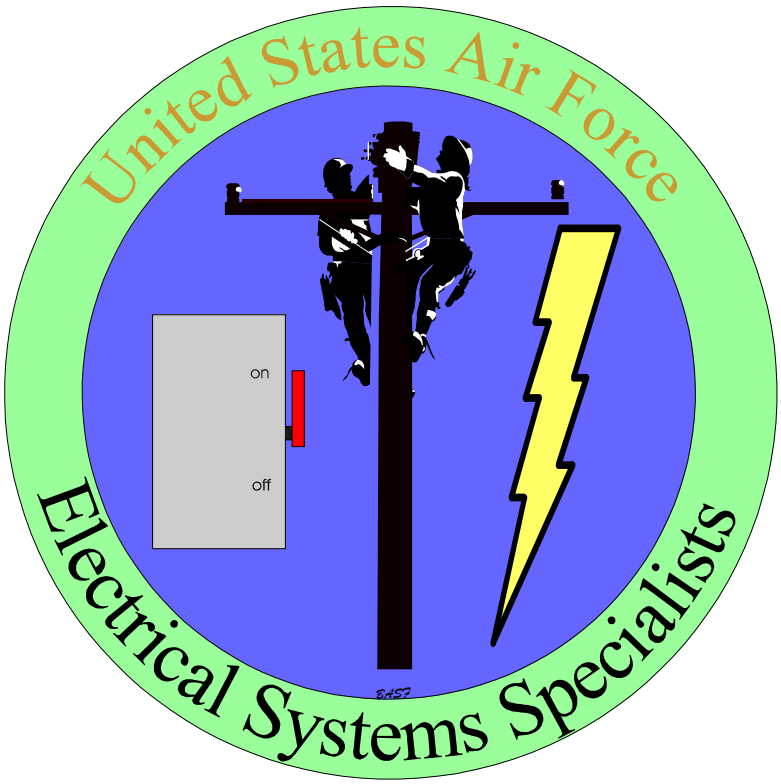
Review Questions
for
Lightning Protection Systems

Question	Answer
1. The purpose of lightning protection grounds is to safely dissipate lightning strikes into the earth.	a. True b. False
2. From a visual inspection, you should be able to determine if _____.	a. All down conductors and ground terminals are intact. b. Corrosion or vibration has weakened any part of the system. c. Additional protection is required. d. All of the above.
3. Repair work performed during maintenance does not need to be tested until continuity tests are performed.	a. True b. False
4. All test agency personnel who could or do perform the tests or inspections should be familiar with ____ and, _____ *Maintenance of Electrical Grounding Systems.*	a. AFP 32 –1065, AFI 91-38 b. AFI 32 – 1060, AFP 91-38 c. AFI 32 – 1065, AFI 91-38 d. AFI 32 – 1065, AFP 91-38

LIGHTNING PROTECTION SYSTEMS

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee check for loose connections?		
2. Did trainee check that all system components were secured?		
3. Did trainee check for additions or alterations on the structure?		
4. Did trainee check for damage to surge suppression?		
5. Did trainee perform all corrective actions?		
6. Did trainee test repairs after making corrections?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.



MAINTAIN

MODULE 22 AFQTP UNIT 3

PRIMARY DISTRIBUTION SYSTEM GROUNDS (22.3.2.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

PRIMARY DISTRIBUTION SYSTEM GROUNDS

Task Training Guide

STS Reference Number/Title:	22.3.2. – Electrical ground systems, maintain primary distribution system grounds
Training References:	• CDC 3E051A, Vol. 3 • National Electric Code, Article 250 • Air Force Instruction 32-1065, Grounding Systems • Air Force Joint Manual 32-1082, Facilities Engineering Electrical Exterior Facilities
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool kit
Learning Objective:	• Given equipment, maintain primary distribution grounds
Samples of Behavior:	• Follow the required steps to maintain primary distribution grounds • Know safety requirements to maintain primary distribution system grounds
Notes:	
• Any safety violation will result in an automatic failure.	

PRIMARY DISTRIBUTION SYSTEM GROUNDS

Background: Distribution system grounds are very important. They allow fuses and other system safety components to operate properly. The most elaborate grounding system you can design may prove ineffective unless the connection of the system to earth is adequate and has a sufficiently low resistance. For safety reasons, electric power systems and equipment are intentionally grounded so that insulation failure results in operation of protective devices to de-energize circuits, thus reducing risk to personnel. The word grounding is used commonly in electric power system work to cover both system grounding and equipment grounding; however, the distinction between system and equipment grounding should be recognized.

A system ground is a connection to ground from one of the conductors of an electric circuit, normally the neutral conductor. The purpose of electrical system grounds is to stabilize voltage to ground and give a low impedance path for fault current. Equipment grounding involves interconnecting and connecting to earth all noncurrent carrying metal parts of an electrical wiring system and equipment connected to the system. The equipment ground is connected to an electrical system ground (neutral) only at the service entrance of a building and should not exceed 25 ohms to ground. The purpose of grounding equipment is to ensure personnel safety, by reducing any charge in an equipment item to near zero volts with respect to ground, without causing a fire or explosive hazard, until the circuit protective device clears the fault.

To perform the task, follow these steps:

Step 1: Keep records.

- Maintain records of the buildings and systems you inspect.
- Review the records for any trends.
- Insure the records include the following:
  - A sketch of the grounding and lightning protection system showing test points.
  - Date action was performed.
  - Name of person performing the action.
  - Inspector's name.
  - General condition of air terminals, conductors, and other components.
  - General condition of corrosion protection measures.
  - Security of attachment for conductors and components.
  - Resistance measurements of the various parts of the ground terminal system.
  - Any corrections taken.
  - Date of repairs.
  - Record test results on any general-purpose form or AFTO 481, Station Ground Resistance Record.

Step 2: Visual inspection.

- Inspect all visible and accessible parts of the system.
- Is the system in good repair.
- Is the system neutral grounded at the service entrance.
- Check for Loose, broken, or missing connections and repair or replace as required.
- Check for Connections or connectors showing signs of overheating, as evidenced by discoloration.
- If connections are corroded or rusted, they should be cleaned and corrective measure taken to prevent reoccurrence.

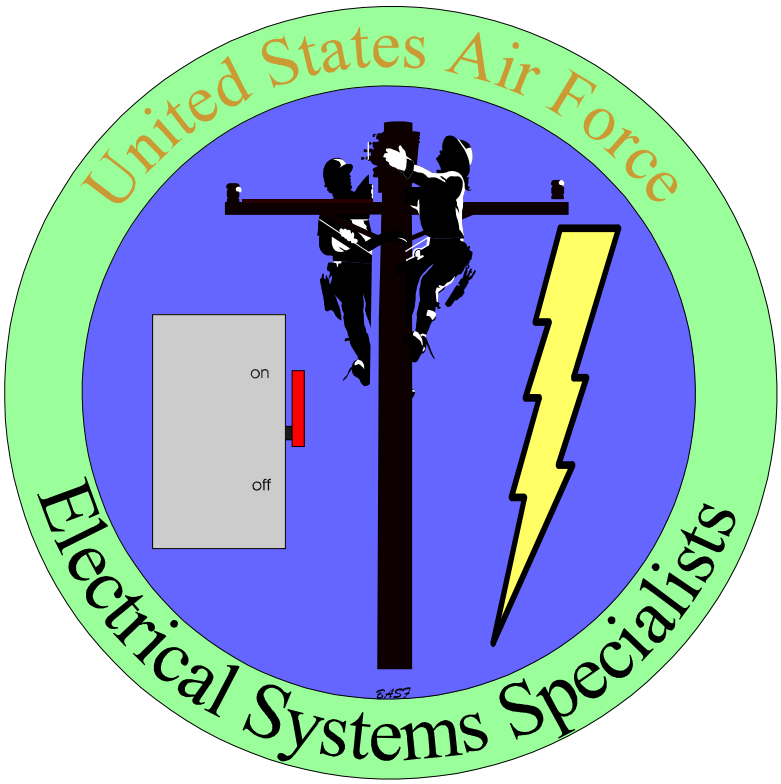
Review Questions
for
Primary Distribution System Grounds

Question	Answer
1. What type of grounding is commonly used in electric power system work?	a. System grounding. b. Equipment grounding. c. Circuit grounding. d. Both a and b.
2. A system ground is a connection to ground from one of the conductors of an electric circuit, normally the _____ conductor.	a. Phase b. Neutral c. Grounding d. None of the above
3. Equipment grounding involves interconnecting and connecting to earth all current carrying parts of an electrical wiring system and equipment connected to the system.	a. True b. False
4. The equipment ground should not exceed __ ohms to ground.	a. 10 b. 15 c. 20 d. 25
5. What should your records of grounding include?	a. A sketch of system b. Inspector's name c. Any corrections taken d. All of the above

PRIMARY DISTRIBUTION SYSTEM GROUNDS

Performance Checklist		
Step	**Yes**	**No**
1. Did the trainee maintain a record of grounding systems?		
2. Did the trainee inspect all visible parts of the system?		
3. Did the trainee take the proper actions to repair any problems that had occurred?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.



TEST

MODULE 22 **AFQTP UNIT 4**

LIGHTNING PROTECTION SYSTEMS (22.4.1.)

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LIGHTNING PROTECTION SYSTEMS

Task Training Guide

STS Reference Number/Title:	22.4.1. – Electrical ground systems, test lightning protection systems
Training References:	• AFI 32 – 1065 • AFP 91 – 38 • CDC 3E051 Set A Vol. 3 • NFPA No.70 (NEC®) • NFPA No.780
Prerequisites:	• Possess as a minimum a 3E031 AFSC.
Equipment/Tools Required:	• General tool kit • Multimeter • Earth resistance tester • File
Learning Objective:	• Given equipment, test lightning protection systems
Samples of Behavior:	• Follow approved methods to test lightning protection systems • Know safety requirements to test lightning protection systems
Notes:	
• Any safety violation is an automatic failure.	

LIGHTNING PROTECTION SYSTEMS

Background: The purpose of lightning protection grounds is to safely dissipate lightning strikes into the earth. They are part of a lightning protection system, which usually includes air terminals (lightning rods), down conductors, arresters, and other connectors or fittings required for a complete system. The sole purpose of a lightning protection system is to protect a building, its occupants, and contents from the thermal, mechanical and electrical effects of lightning. You need a fall-of-potential meter to measure system-to-ground resistance and a digital ohmmeter for component continuity checks. Be sure to use instruments designed specifically for measuring the resistance of earth-ground systems. The instruments must be able to measure 10 ohms (plus or minus 10 percent) for ground resistance tests and 1 ohm (plus or minus 10 percent) for continuity testing. Be sure to follow the manufacturer's instruction manual when using the instruments (except as modified under "test procedures").

Agency responsibilities.

- The reason for periodic testing of grounding systems is to confirm their integrity.
- Also, NFPA No.70 (NEC®), NFPA No.780 (Lightning Protection Code®), and AFJMAN 91–201, Explosive Safety Standards, and AFI 32–1065 have requirements and procedures that only testing can confirm.
- As a rule, the using agency should do the visual inspections.
- The Base Civil Engineer (BCE) electrical shop personnel should do the resistance tests.
- The user or the electrical shop personnel can do the continuity checks.

Record keeping.

- Accurate records are important for the continuity of testing between different personnel and also show changes in readings over a period of time.
- The following is a suggested list of record keeping procedures and what the records should show in addition to the date of the inspection or test.
- The general condition of air terminals, conductors, and other components.
- The general condition of corrosion protection measures.

To perform the task, follow these steps:

Step 1: Visually inspect system.

- A visual inspection should be performed while testing the system.

Step 2: Perform Grounding system resistance test.

- In Figure 1, you see auxiliary probe locations for fall-of-potential ground-resistance tests.

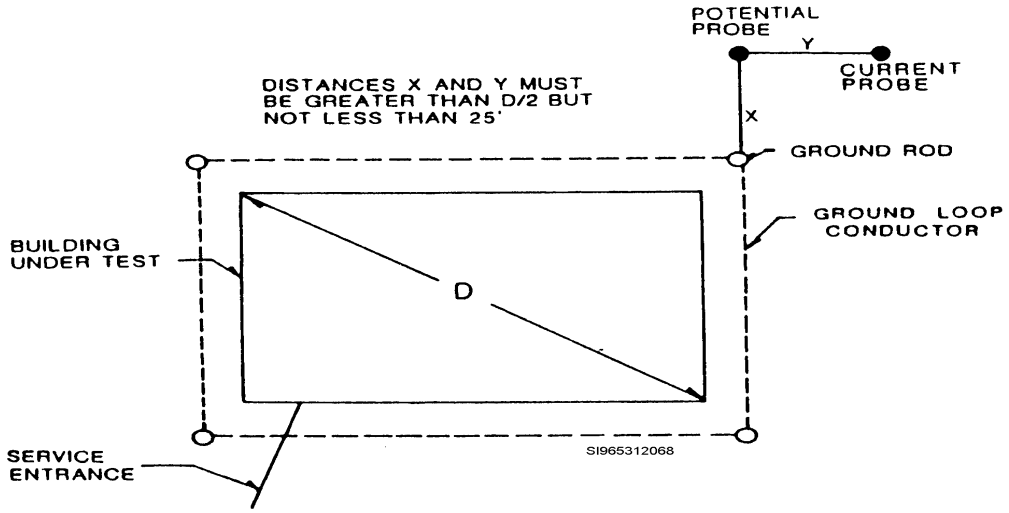


Figure 1, Auxiliary Probe Locations for Fall-Of Potential Ground Resistance Test

- Conduct this test at the corner of the building opposite the electrical service entrance.
- Do not disconnect the electrical service from other ground connections, as there is the danger of it inadvertently being left disconnected. Also, disconnecting a ground may cause a shock hazard.
- Connect the proper lead of the fall-of-potential meter to the ground rod at this location.
- Place the potential reference probe over one-half the diagonal distance of the building, but not less than 25 feet, and connect to P1 of meter.
- Place the current reference probe 90° from the potential reference probe and the ground rod under test.
- Place this probe over one-half the diagonal distance of the building and at least 25 feet from the potential reference probe, and connect to C1 of meter.
- For buildings without a ground loop conductor, do this test at each corner ground rod.
- Resistance should be less than 25 ohms (10 ohms for explosive or communications facilities where the system connects to a lightning protection system).

Step 3: Continuity check for separately mounted lightning protection system (mast or overhead shield wire).

- Figure 2 illustrates a mast and overhead shield wire protection system.

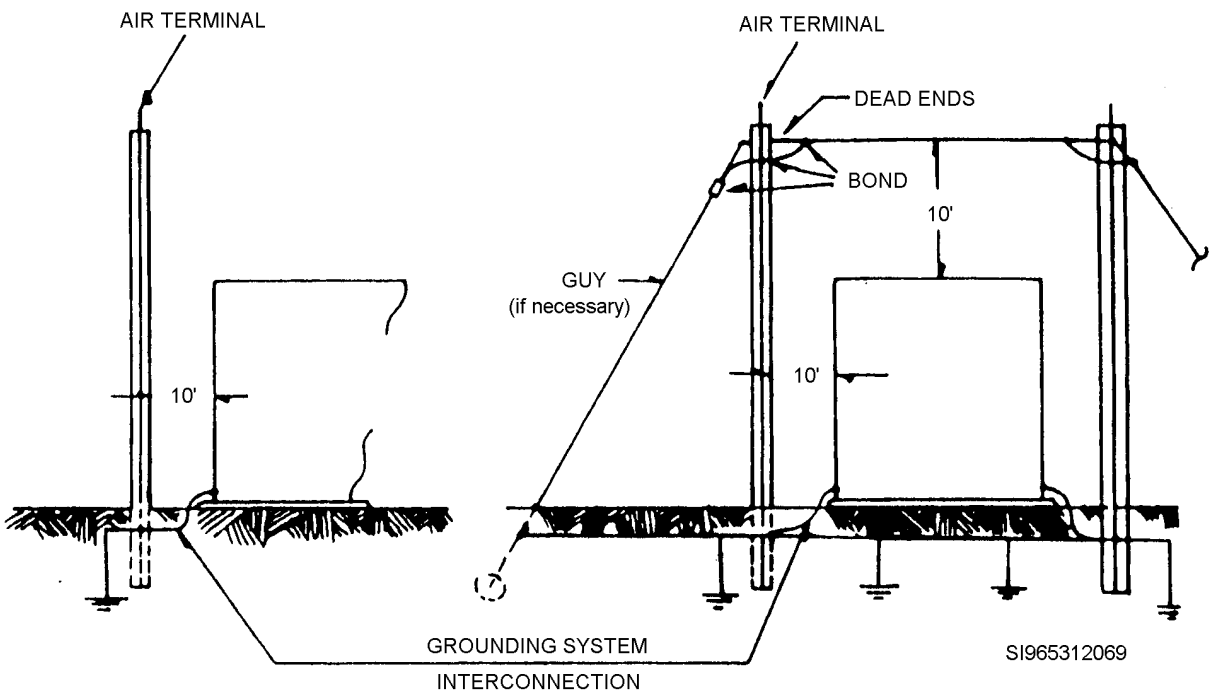


Figure 2, Mast and Overhead Shield Wire Protection System

- Connect one lead of a digital ohmmeter to the highest point on the pole or at the overhead shield wire connection.

NOTE:
Zero ohmmeter before taking continuity reading. This will prevent you from reading the resistance of the test leads.

- Connect the other lead to the ground rod at the base of the pole.
- If using a wire reel, remember to subtract the resistance of the reel from ohmmeter reading.
- If the resistance is not less than 1 ohm, check for deficiencies and make repairs.
- Visually inspect overhead wires with binoculars.

NOTE:
Also ensure that continuity exists between the two down conductors on a mast or overhead shield system. It could be possible that the conductors have corroded and created an open in the loop.

Step 4: Continuity check for integrally mounted lightning protection systems.

- Perform this test by firmly attaching one lead of a digital ohmmeter to a corner ground rod.
- Now connect the other lead to the air terminal (or metallic body).
- Record this reading on the data sheets.
- If using a wire reel, remember to subtract the resistance of the reel from ohmmeter reading.
- Repeat the test from the ground rod to remaining test points of the building.

NOTE:
You can also do the tests from ground rod to nearest corner air terminal and from that corner terminal to the other corner terminals.

- If the resistance is not less than 1 ohm, check for deficiencies and make repairs.

Review Questions
for
Lightning Protection Systems

Question	Answer
1. The instruments used to measure resistance must read ___ ohms, plus or minus ____ percent for ground resistance tests.	a. 10 – 5 b. 10 – 10 c. 25 – 10 d. 25 - 5
2. A visual inspection should be able to tell you if the system follows the Lightning Protection Code in all areas.	a. True b. False
3. The current reference probe is placed ____from the potential reference probe and the ground rod under test.	a. 45° b. 60° c. 90° d. 180°
4. Continuity check for integrally mounted lightning protection systems is performed using a _____.	a. Voltmeter. b. Ammeter. c. Ohmmeter. d. None of the above.
5. The Base Civil Engineer (BCE) electrical shop personnel are responsible for resistance tests.	a. True b. False
6. Each facility or area should have records that include a sketch of the grounding system as well as documentation of all inspections and tests.	a. True b. False

LIGHTNING PROTECTION SYSTEMS

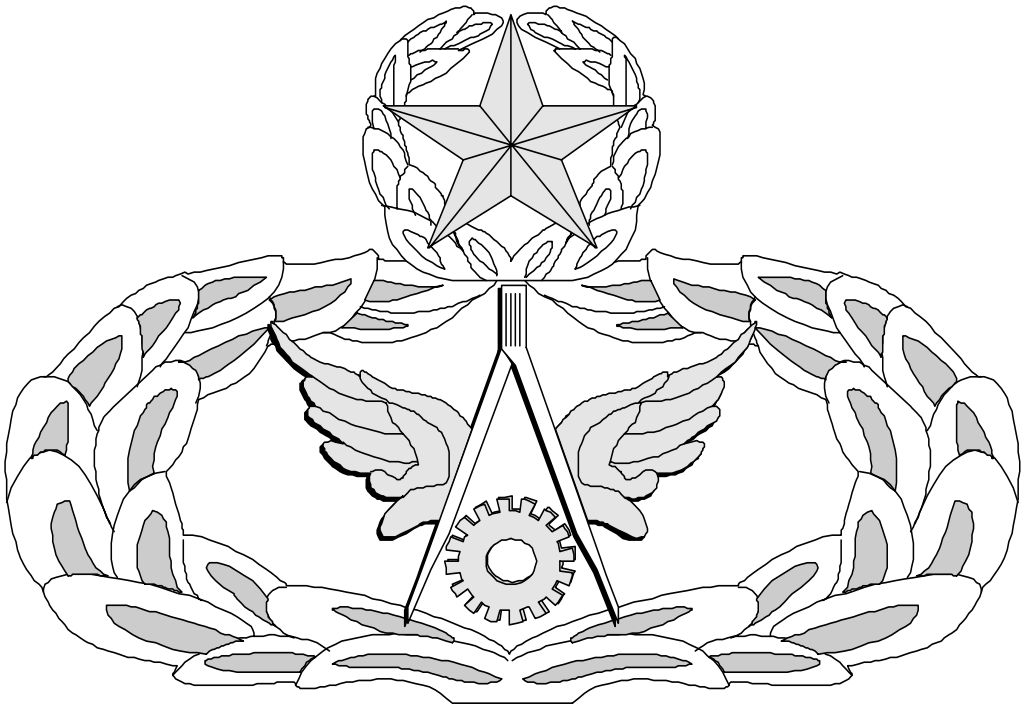
Performance Checklist		
Step	**Yes**	**No**
1. Did trainee perform the visual inspection?		
2. Did trainee place potential reference probe over one-half the diagonal distance of the building, but not less than 25 feet?		
3. Did trainee place current reference probe over one-half the diagonal distance of the building, at least 25 feet, 90 degrees from potential probe and the ground rod under test?		
4. Did trainee properly connect ohmmeter between ground rod and all test points?		
5. Did trainee zero ohmmeter before taking reading?		
6. Did trainee annotate all ohm readings on the proper documents?		
7. Did trainee annotate all corrective actions taken?		
8. Did trainee repair all damaged components found during testing?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

Air Force Civil Engineer

QUALIFICATION TRAINING PACKAGE (QTP)

REVIEW ANSWER KEY



For

ELECTRICAL SYSTEMS

(3E0X1)

MODULE 22

ELECTRICAL GROUND SYSTEMS

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LIGHTNING PROTECTION SYSTEMS

(3E0X1-22.3.1.)

Question	Answer
1. The purpose of lightning protection grounds is to safely dissipate lightning strokes into the earth.	a. True
2. From a visual inspection, you should be able to determine if _____.	d. All of the above.
3. Repair work performed during maintenance does not need to be tested until continuity tests are performed.	b. False
4. All test agency personnel who could or do perform the tests or inspections should be familiar with ____ and, _____ *Maintenance of Electrical Grounding Systems.*	d. AFI 32 – 1065, AFP 91-38

PRIMARY DISTRIBUTION SYSTEM GROUNDS

(3E0X1-22.3.2.)

Question	Answer
1. What type of grounding is commonly used in electric power system work?	d. Both a and b.
2. A system ground is a connection to ground from one of the conductors of an electric circuit, normally the _____ conductor.	b. Neutral
3. Equipment grounding involves interconnecting and connecting to earth all current carrying parts of an electrical wiring system and equipment connected to the system.	b. False
4. The equipment ground should not exceed __ ohms to ground.	d. 25
5. What should your records of grounding include?	d. All of the above

LIGHTNING PROTECTION SYSTEMS

(3E0X1-22.4.1.)

Question	Answer
1. The instruments used to measure resistance must read ___ ohms, plus or minus ____ percent for ground resistance tests.	b. 10 – 10
2. A visual inspection should be able to tell you if the system follows the Lightning Protection Code in all areas.	a. True
3. The current reference probe is placed ____from the potential reference probe and the ground rod under test.	c. 90°
4. Continuity check for integrally mounted lightning protection systems is performed using a _____.	c. Ohmmeter
5. The Base Civil Engineer (BCE) electrical shop personnel are responsible for resistance tests.	a. True
6. Each facility or area should have records that include a sketch of the grounding system as well as documentation of all inspections and tests.	a. True